

Maternal mortality in adolescents compared with women of other ages: evidence from 144 countries



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Summary

Background Adolescents are often noted to have an increased risk of death during pregnancy or childbirth compared with older women, but the existing evidence is inconsistent and in many cases contradictory. We aimed to quantify the risk of maternal death in adolescents by estimating maternal mortality ratios for women aged 15–19 years by country, region, and worldwide, and to compare these ratios with those for women in other 5-year age groups.

Methods We used data from 144 countries and territories (65 with vital registration data and 79 with nationally representative survey data) to calculate the proportion of maternal deaths among deaths of females of reproductive age (PMDF) for each 5-year age group from 15–19 to 45–49 years. We adjusted these estimates to take into account under-reporting of maternal deaths, and deaths during pregnancy from non-maternal causes. We then applied the adjusted PMDFs to the most reliable age-specific estimates of deaths and livebirths to derive age-specific maternal mortality ratios.

Findings The aggregated data show a J-shaped curve for the age distribution of maternal mortality, with a slightly increased risk of mortality in adolescents compared with women aged 20–24 years (maternal mortality ratio 260 [uncertainty 100–410] vs 190 [120–260] maternal deaths per 100 000 livebirths for all 144 countries combined), and the highest risk in women older than 30 years. Analysis for individual countries showed substantial heterogeneity; some showed a clear J-shaped curve, whereas in others adolescents had a slightly lower maternal mortality ratio than women in their early 20s. No obvious groupings were apparent in terms of economic development, demographic characteristics, or geographical region for countries with these different age patterns.

Interpretation Our findings suggest that the excess mortality risk to adolescent mothers might be less than previously believed, and in most countries the adolescent maternal mortality ratio is low compared with women older than 30 years. However, these findings should not divert focus away from efforts to reduce adolescent pregnancy, which are central to the promotion of women's educational, social, and economic development.

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Introduction

Many of today's 1·2 billion adolescents¹ (ie, people aged 10–19 years) were born around the turn of the millennium, when world leaders first pledged to achieve the Millennium Development Goals (MDGs). These young people have benefited from improvements associated with the MDGs, including a 47% drop in maternal mortality between 1990 and 2010.² However, studies of maternal mortality tend to calculate single mortality figures for women and girls of all ages. Separate estimates for adolescent mothers are needed to allow the assessment of progress, and potential additional risk, in this population.

Each year an estimated 16 million women aged 15–19 years give birth,³ and a further million become mothers before age 15 years.⁴ In most countries these adolescent births are concentrated among poorer, less educated women, and early motherhood further compounds disadvantage by disrupting school attendance and limiting future livelihood opportunities. Context can vary greatly both between and within countries. Most adolescent births in developing countries are planned and occur within the context of marriage. Thus these

pregnancies are driven by traditional practices and norms, and encouraged and sanctioned by families and the wider community. However, in most developed countries, as well as in Latin America and the Caribbean, and some parts of sub-Saharan Africa, most pregnancies in adolescents occur outside of marriage, and are usually unplanned.

The potential health, social, and economic disadvantages that adolescent mothers face are widely recognised, and their right to access adequate reproductive health care has been enshrined in a series of important international agreements and documents since 1990.^{5–8} However, mortality risks to adolescent mothers have not been accurately or comprehensively quantified. A frequently cited statistic is that girls younger than 15 years are several times more likely to die from maternal causes than women in their early 20s,⁹ and those aged 15–19 years are also at additional risk.^{10,11} Figures based on a UN report published more than 20 years ago,¹² which states that girls younger than 15 years are five times and adolescents aged 15–19 years twice as likely to die from maternal causes as older women, have only recently been challenged on the basis of a compilation of 13 datasets,¹³ which suggests a

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reduced risk for the younger age group. A more recent analysis¹⁴ of data for 38 countries estimated that the risk of death per birth for adolescents aged 15–19 years is only 28% higher than for women aged 20–24 years.

Almost all community-based studies in developing countries have suggested an increased risk of maternal mortality for adolescents, but estimates of the size of the increased risk vary greatly. Studies from developed countries are even less consistent: national estimates from vital registration in the USA suggest that adolescents have a lower maternal mortality ratio than women older than 20 years,¹⁵ and statistics from the UK¹⁶ and Canada¹⁷ both show the maternal mortality ratio for women and girls younger than 20 years to be slightly higher than for women aged 20–24 years, but lower than for those older than 25 years. Conversely, data from Australia suggest that the maternal mortality ratio for women younger than 20 years is higher than for all age groups apart from women older than 40 years.¹⁸ Some evidence from both developing and developed countries also suggests that risks are greater for younger adolescents, with girls aged 15 years or younger having higher mortality than older adolescents.¹⁹

We aimed to extend existing knowledge on this issue by producing direct country-level estimates of maternal mortality for adolescents aged 15–19 years, using vital registration data (where available) or nationally representative surveys. We also calculated age-specific estimates for other 5-year age groups, ranging from 20–24 to 45–49 years, to enable comprehensive comparisons of the risk faced by women at different ages.

Methods

Data sources

Many surveys and censuses collect information about maternal deaths via the direct sisterhood method. With this method, survey respondents are asked to give the dates of birth and death (if applicable) for all of their siblings (ie, those born to the same mother). If a sister died during the reference period (usually the preceding 6 years), the respondent is asked to state whether the death occurred during pregnancy or within 2 months of the end of pregnancy. However, evidence suggests that data obtained in this way systematically underestimate true mortality.²⁰ These data can lead to biased estimates of maternal mortality, but not necessarily to biased values of the proportion of maternal deaths among deaths of females of reproductive age (PMDF).²¹ For this reason, we have used PMDF as the basis for calculations of age-disaggregated maternal mortality ratios. For consistency, we have used PMDF even for data sources not reliant on the sisterhood method. This methodological approach, including adjustment techniques, is based on the method used by WHO, UNICEF, the UN Population Fund, and the World Bank to estimate maternal mortality ratios.²

Countries or territories with populations of 250 000 or greater were considered for inclusion in the analysis

($n=185$). Countries were allocated to groups according to the type of data available, with group A countries holding good vital registration data, group B countries holding a lesser quality national data source, and group C countries having no national sources (table 1). Nearly all group A countries have a low overall maternal mortality ratio, and most are high-income or upper-middle-income countries as defined by the World Bank.²² To build up a worldwide and regional view of adolescent maternal mortality, other, less reliable sources of data also have to be used, hence our inclusion of group B countries.

Vital registration data were available mainly from the WHO mortality database for the years 1985 onwards, up to the most recent year available by May, 2011. Other types of data were obtained from published sources—mainly Demographic and Health Survey (DHS) reports, but also others, such as reports and datasets from sample health surveillance systems. Health surveillance is the continuous, systematic collection, analysis, and interpretation of health-related data, and sample systems involve the use of a nationally representative sample rather than a census approach (appendix pp 1–3). We accessed the highest-quality data source for each country to obtain the most recent age-disaggregated information available.

Main analyses

We selected the most recent time period on the basis of available data for each of the 144 countries. Countries with vital registration data had more reliable data for more time periods than other countries, but even for these countries some adjustments and approximations were necessary. Our approach in countries with vital registration data was to pool mortality data from the most recent 10-year period for which they were available (unless data were available for fewer than 10 years, in which case the data from all available years were pooled). A 10-year period was selected because in most countries insufficient numbers of maternal deaths occurred to allow for age disaggregation for shorter time periods. The selected data periods for each country are shown in the appendix (pp 1–3). Deaths were counted within 5-year age groups: 15–19, 20–24, 25–29, 30–34, 35–39, 40–44, and 45–49 years. If data were missing for 1 or more years, they were imputed by taking the mean number of deaths from the nearest 4 years for that age group. For example, if data were missing for the second year in the 10-year period, the figure for that year was assumed to be the mean of the first, third, fourth, and fifth years, or if data were missing for the fifth of 10 years, the figure for that year was assumed to be the mean of the third, fourth, sixth, and seventh years. Recorded deaths with an unknown age were distributed proportionally across the age range. Where vital registration data were not available, the most recent survey data were accessed from published reports.

For each of the seven age groups, we calculated an observed PMDF for each country. The observed PMDF is

See Online for appendix

	Definition	Number of countries or territories (%)	Percentage of total births in all 185 countries and territories*	Percentage of total births to mothers aged 15–19 years in all 185 countries and territories*
Group A	Countries with complete vital registration data, with good attribution of cause of death—ie, earliest year of data available is before 1996; latest year of data available is after 2002; data are available for more than half of the range of years; estimated completeness of death registration is greater than 84%; and deaths coded to ill-defined cause codes (ICD-10 R codes) do not exceed 20%	65 (35%)	15.7%	11.5%
Group B	Countries with other types of national data (eg, incomplete vital registration data, sample survey data)	82 (44%)	77.4%	84.4%
Group C	No national data for maternal mortality available	38 (21%)	6.9%	4.1%

ICD=International Classification of Diseases. *Countries and territories with populations of less than 250 000 were excluded.

Table 1: Quality of country-level data

the number of maternal deaths as a proportion of all-cause female deaths in each age group. These numbers are subject to various biases and needed to be adjusted before they could be used to calculate age-disaggregated maternal mortality ratios. The first adjustment was for under-reporting of maternal deaths—a factor long recognised to produce substantially reduced estimates of maternal mortality ratio if ignored. To account for this issue, the method used by WHO and the other agencies² involved the application of an adjustment factor of 1.5 to the PMDF for countries with vital registration data and 1.1 for countries without, unless country-specific evidence suggested that a different factor should be used.

Most studies into under-reporting of maternal mortality do not break down their results by age, but the two that do^{23,24} suggest that under-reporting in the 15–19 years age group is about 50%, compared with about 30% in the 20–24 years age group and about 40% in the 25 years and older age groups. In the absence of more detailed, country-specific or region-specific evidence about how under-reporting of maternal mortality varies by age group, we assumed that the estimates from these two studies apply in all countries, and applied adjustment factors as detailed in table 2. If the overall adjustment factors for some countries with vital registration data were different from 1.5, the age-specific adjustment factors in table 2 were applied pro rata.

A second adjustment was necessary to account for misclassification of maternal deaths. If data are collected via a survey, sometimes respondents are only asked for the dead woman's pregnancy status at the time of her death, which means that deaths from accidental or incidental causes can be included in estimates of maternal mortality. This classification is known as pregnancy-related mortality, rather than meeting the strict definition of maternal mortality (appendix p 4). On the basis of the approach taken by WHO and the other agencies² to adjust for this misclassification, in sub-Saharan African countries with DHS data or similar, the PMDF was multiplied by 0.9, and for other countries with DHS data, the PMDF was multiplied by 0.85. The

	Countries with vital registration data (group A or B)	Countries without vital registration data (all group B)
<20 years	1.6	1.15
20–24 years	1.4	1.05
≥25 years	1.5	1.10

Table 2: Age-specific adjustment factors to compensate for under-reporting

application of the two adjustment factors resulted in an adjusted PMDF for each age group in each country.

We then calculated age-specific maternal mortality for each age group in each country as follows:

$$\text{Maternal mortality ratio} = \frac{\text{PMDF} \times \text{ACD}}{B} \times 100\,000$$

where PMDF is the adjusted PMDF for that age group, ACD is the estimated number of all-cause female deaths in that age group, and B is the estimated number of livebirths in that age group. The maternal mortality ratio is reported as the number of maternal deaths per 100 000 livebirths, hence the multiplier of 100 000.

We used UN Population Division estimates of the number of all-cause female deaths in each age group. The number of deaths in each year was estimated by dividing by five the UN Population Division estimate for the 5-year period in which the year fell. Within age groups, the estimated number of deaths in each of the 10 selected years was then summed to give an estimate of the total number of deaths of women in each age group across the 10-year period. The UN Population Division started reporting age-specific numbers of deaths in 1995; estimates related to the years before 1995 are not broken down by age group, and only the total is reported. For a few of the countries included in the analysis, the only available data for maternal mortality predated 1995. In these cases, if vital registration data were available, these were used for the age-specific estimates. If no vital registration data were available, the total number of

female deaths in the relevant years (as estimated by the UN Population Division) was assumed to have the same age distribution as in the years 1995–2000.

We used UN Population Division estimates of the number of livebirths to women in each 5-year age group. We estimated the number of births in each year by dividing by five the UN Population Division estimate for the 5-year period in which the year fell. Within age groups, we then summed the estimated number of births in each of the reference years to give an estimate of the total number of births to women in each age group across the whole reference period. As with deaths, if any of the reference years were before 1995, the total number of livebirths in the relevant years was assumed to have the same age distribution as in the years 1995–2000.

To calculate regional estimates (based on WHO regions²), we first estimated the annual number of births and maternal deaths for each 5-year age group in each country by dividing our estimates of the total number of births and maternal deaths in that age group by the number of years in the reference period. We then summed these estimates across all countries in the region. This method yielded age-specific estimates of regional maternal mortality ratios that are effectively weighted averages of the country-specific maternal mortality ratio estimates. Thus, even countries with zero maternal deaths in one or more age groups were included in the regional estimates. The same approach was used to derive an estimate for all countries combined.

Sensitivity analyses

To test the effect on the results of the assumptions made in the main analyses, we did several sensitivity analyses. First, we tested whether the pooling of 10-year data periods for countries with vital registration data masked variations over time. Most countries did not record sufficient numbers of maternal deaths in each 5-year age group to permit disaggregation by 5-year data periods, but a few did. For Mexico, Russia, South Africa, and the USA, we reran the calculations for the two 5-year periods that made up the 10-year reference period, and compared the results against those for the original 10-year period.

Second, to test the effect of distributing age-unknown maternal deaths proportionally across the age range for countries with vital registration data, we ran a sensitivity analysis for countries with fairly large numbers of age-unknown maternal deaths. Only seven countries had any maternal deaths with unknown age: Argentina, Brazil, Colombia, Guatemala, Mexico, Peru, and South Africa. Only in Colombia and Peru did these age-unknown maternal deaths constitute more than 0.4% of all recorded maternal deaths (1.0% in Colombia and 1.3% in Peru). For these two countries, we reran the analysis with an assumption that all age-unknown maternal deaths were in the 15–19 years age group and compared the results against our main findings.

Third, to test the effect of the age-specific adjustment factors, for a selection of countries we reran the analysis twice: once with no age variation in the adjustment factors (ie, the adjustment factor for all age groups was 1.5 in countries with vital registration data and 1.1 in those without) and once with more pronounced age variation (ie, in countries with vital registration data the adjustment factors were 2.0 for the 15–19 years age group, 1.0 for the 20–24 years age group, and 1.5 for the 25 years and older age groups, and in those without vital registration data the factors were 1.19 for the 15–19 years age group, 1.01 for the 20–24 years age group, and 1.10 for the 25 years and older age groups). We ran this sensitivity analysis for five countries with vital registration data (Argentina, Egypt, Italy, Romania, and Trinidad and Tobago) and five without (Afghanistan, Botswana, Haiti, India, and Timor-Leste).

Uncertainty estimates

The method for calculating uncertainty estimates varied according to whether the data source was vital registration or a survey. For countries with survey data, the 95% CI around the unadjusted PMDF was calculated separately for each 5-year age group as follows:

$$95\% \text{ CI} = p \pm \left(1.96 \times \text{DEFF} \times \sqrt{\frac{p[1-p]}{n}} \right)$$

where p is the unadjusted PMDF for that age group, DEFF is the design effect for the maternal mortality ratio (as provided in the survey report) or, if that was not reported, the overall design effect, and n is the number of all-cause deaths of women in that age group as identified in the survey. In a few cases, this calculation resulted in the lower boundary being less than zero; when this occurred, the lower boundary was censored at zero. Adjustment factors were then applied to the upper and lower boundaries of the PMDFs in the same way as for the main PMDF estimates.

For the remaining countries, a different approach was necessary because the data were from a census rather than a sample, and therefore the main source of uncertainty was judged to be data quality rather than sampling error. Since data quality was addressed via the adjustment factors shown in table 2, uncertainty estimates were calculated by varying these factors. Wilmoth and colleagues²⁵ took a similar approach, suggesting that “likely errors in these adjustment factors fall in a range of, roughly, plus or minus 10%”. We therefore calculated lower and upper boundaries for the unadjusted PMDFs by multiplying the PMDF adjustment factors for each age group by 0.9 and 1.1, respectively.

For all 5-year age groups in all countries, we then used the upper and lower boundaries of the adjusted PMDFs to calculate upper and lower boundaries for the number of maternal deaths in each age group, and thus age-specific maternal mortality ratios, in the same way as for the main maternal mortality ratio estimates.

We calculated uncertainty estimates for regions using the country-level upper and lower boundaries for the estimates of the number of maternal deaths. For each country in a region, we divided the upper and lower boundaries by the number of years in the reference period to give an upper and lower boundary for the annual number of maternal deaths. We then summed the upper and lower boundaries across all countries in the region. These numbers were divided by the regional estimate of the annual number of births and multiplied by 100 000 to yield upper and lower boundaries for the maternal mortality ratio estimate. The same approach was used to derive an uncertainty estimate for all countries combined.

Role of the funding source

AVC conceived the study while employed by one of the sponsors (WHO Department of Maternal, Newborn, Child and Adolescent Health). This sponsor also provided the source data (with assistance from the WHO Department of Reproductive Health and Research), approved the methods used, and commented on each draft of this report. The corresponding author had full access to all the data used in the analyses, and the authors had final responsibility for the decision to submit for publication.

Results

Maternal mortality data were available for 147 of the 185 countries or territories considered for inclusion (65 in group A and 82 in group B). However, for two group B countries (Brunei and Fiji) too few maternal deaths occurred to attempt an age disaggregation, and for one group B country (Montenegro) the available data could not be disaggregated by age. Therefore 144 countries remained for which a direct estimate could be made (no estimates were made for countries in group C). These 144 countries account for 93% of the world's annual births.

All estimated country-level, age-specific maternal mortality ratios are listed in the appendix (pp 5–13). Use of these maternal mortality ratios to estimate total annual numbers of deaths showed that 10% of maternal deaths each year in the 144 countries included in the study were to adolescents aged 15–19 years (compared with 12% of births) and that the 20 countries with the most adolescent maternal deaths (mostly large countries in sub-Saharan Africa and Asia) accounted for 82% of the world's total. In order of annual number of adolescent maternal deaths, these countries were: Nigeria, India, Ethiopia, Afghanistan, Democratic Republic of the Congo, Tanzania, Pakistan, Kenya, Sudan, Indonesia, Uganda, Mozambique, Mali, Cameroon, Chad, Niger, Zimbabwe, Nepal, Guinea, and Bangladesh.

Despite having large numbers of adolescent maternal deaths, however, in several of these countries (India, Democratic Republic of the Congo, Indonesia, Mozambique, Cameroon, Niger, and Bangladesh) the adolescent maternal mortality ratio estimate was the lowest out of all the 5-year age groups. Of course, the

countries with the highest number of adolescent maternal deaths tended also to be the countries with the highest number of maternal deaths overall, with a few exceptions—eg, Chad, Guinea, Mali, and Nepal were among the 20 countries with the most adolescent maternal deaths, but not among the 20 countries with the most maternal deaths overall.

Our results confirm the existence of the widely cited J-shaped curve for age-specific maternal mortality (figure 1). This J-shaped pattern was seen for all regions apart from southeast Asia, where the maternal mortality ratio for the 15–19 years age group was lower than for 20–24 years age group. Notably, in Africa and the Americas little excess mortality for adolescents was apparent. By contrast, in Europe, western Pacific, and the eastern Mediterranean the J shape was more pronounced, with excess mortality only really becoming an issue after age 34 years.

Overall, excess maternal mortality for adolescents compared with women in their early 20s was not very large (figure 1, table 3). Although the results show that in many developed and developing countries pregnancy during adolescence carries a higher risk of mortality than does pregnancy in a woman's 20s, our findings do not agree with the previous estimate of twice the risk.⁹ Furthermore, the uncertainty estimates were wide (table 3) and overlap for the 15–19 and 20–24 years age groups in all regions, suggesting that there might be no difference between these two age groups, except perhaps in Europe, where the uncertainty estimates only narrowly overlap.

The apparently heightened risk for adolescents was much lower than for women aged 35 years and older (figure 1). The risk in women aged 45–49 years was especially high (table 3, appendix pp 5–13), although for many countries we were unable to estimate the maternal mortality ratio for this age group because of small numbers of births and maternal deaths. However, the

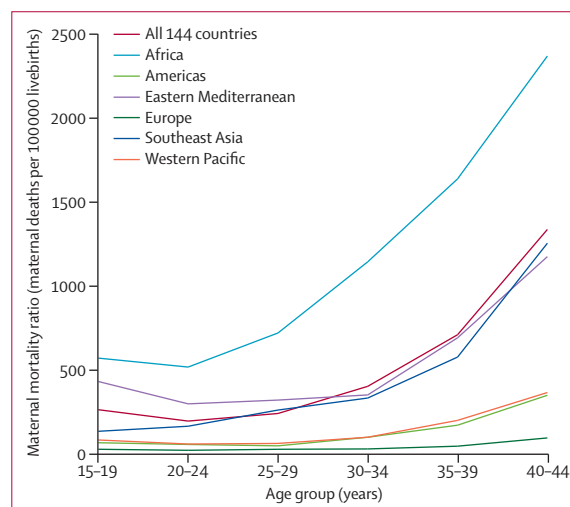


Figure 1: Age-specific maternal mortality ratios, by region

	15–19 years	20–24 years	25–29 years	30–34 years	35–39 years	40–44 years	45–49 years
All 144 countries	260 (100–410)	190 (120–260)	240 (140–330)	400 (220–570)	710 (320–1100)	1300 (220–2400)	2800 (660–6200)
Africa	570 (230–900)	510 (290–740)	720 (400–1000)	1100 (650–1600)	1600 (730–2500)	2400 (540–4000)	3900 (0–8900)
Americas	61 (45–77)	50 (38–61)	41 (32–50)	94 (74–120)	160 (130–200)	340 (240–440)	1100 (400–1800)
Eastern Mediterranean	430 (140–710)	290 (180–410)	320 (200–440)	350 (180–520)	690 (330–1000)	1200 (360–2000)	1600 (0–3800)
Europe	22 (17–27)	15 (13–17)	21 (18–25)	24 (20–28)	41 (34–48)	90 (69–110)	190 (80–310)
Southeast Asia	130 (48–210)	160 (110–210)	260 (180–330)	330 (160–490)	570 (240–910)	1300 (0–2900)	2300 (0–5200)
Western Pacific	77 (0–190)	53 (35–71)	56 (36–76)	94 (50–140)	190 (57–330)	360 (0–760)	2700 (0–5700)

Data are maternal mortality ratios (maternal deaths per 100 000 livebirths) with uncertainty estimates.

Table 3: Age-specific maternal mortality ratios and uncertainty estimates, by region

	15–19 years	20–24 years	25–29 years	30–34 years	35–39 years	40–44 years
All 144 countries	260 (100–410)	190 (120–260)	240 (140–330)	400 (200–570)	710 (320–1100)	1300 (220–2400)
Good vital registration data (group A; n=65 countries)	31 (28–34)	23 (21–26)	18 (16–20)	32 (29–36)	59 (53–65)	120 (110–130)
Other vital registration data (n=25 countries)	58 (52–63)	53 (48–58)	80 (72–88)	120 (110–140)	190 (170–210)	260 (240–290)
Non-vital-registration data (n=54 countries)	320 (120–520)	220 (140–310)	320 (190–440)	560 (300–810)	1000 (440–1600)	1700 (240–3200)

Data are maternal mortality ratios (maternal deaths per 100 000 livebirths) with uncertainty estimates.

Table 4: Age-specific maternal mortality ratios, by data source

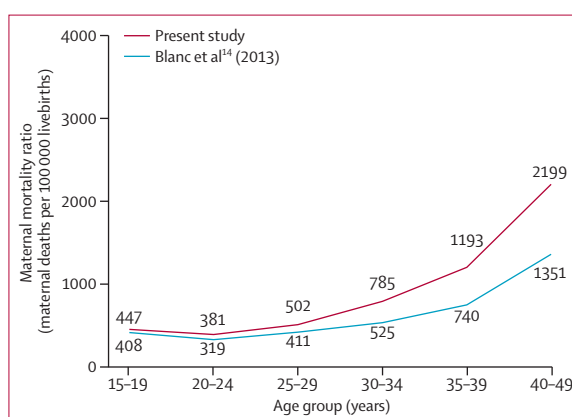


Figure 2: Comparison of age-specific maternal mortality ratios for 38 countries against Blanc and colleagues' study¹⁴

uncertainty estimates were wide, so only in Europe, the Americas, and southeast Asia can we be confident that women aged 35 years and older are indeed at higher risk than adolescents and women aged 20–24 years.

Notably, the pattern of age-specific maternal mortality varied greatly between countries. In about a fifth of the countries included in the study, the maternal mortality ratio estimate for women aged 15–19 years was at least twice as high as that for women aged 20–24 years. This group includes countries as disparate as Australia, Italy, Burundi, Bolivia, and Chad. However, in more than a third of the countries, adolescents had the lowest maternal mortality ratio of all age groups. This group contains several countries with very large populations (eg, Bangladesh, India, and Indonesia), and several sub-Saharan African countries with very high maternal

mortality ratios (eg, Central African Republic, Democratic Republic of the Congo, and Zambia). The remaining countries fit somewhere between these two patterns, with women aged 15–19 years having the same or somewhat higher maternal mortality ratios than women in their 20s. No obvious groupings were apparent for countries with these different patterns of age-distribution for maternal mortality; both developed and developing countries, and countries from all geographical areas, are represented within each group.

The uncertainly estimates for group A countries were quite small for the 15–19 and 20–24 years age groups: in several countries where the maternal mortality ratio for the 15–19 years age group was higher than for the 20–24 years age group, the uncertainty estimates do not overlap (eg, Australia, France, Greece, and the UK). Similarly, the uncertainty estimates do not overlap in a smaller number of group A countries where the maternal mortality ratio in the 20–24 years age group was higher than in the 15–19 years age group (eg, Poland, Portugal, and Uruguay), but the differences were quite small. The uncertainty estimates were much greater for group B countries, and most estimates based on survey data overlap between age groups. For a few group B countries (particularly those with vital registration data), however, the uncertainty estimates do not overlap, and we can therefore be more confident that the age patterns in maternal mortality ratios are an accurate representation of reality. For several of these countries (including Albania, Botswana, Chad, Georgia, and Mongolia) the maternal mortality ratio for ages 15–19 years was greater than for ages 20–24 years, whereas in Armenia and Egypt the maternal mortality ratio was lower in the 15–19 years age group.

Table 4 shows that, although a bigger difference was seen between the maternal mortality ratios for the 15–19 years and 20–24 years age groups in countries without vital registration data, the basic J shape is evident irrespective of the data source. This finding suggests that the differences between groups of countries cannot be fully accounted for by differences in types of data used. However, for all three types of data source, the uncertainty estimates for the 15–19 years age group overlap with those for the 20–24 age group, which means the J shape might not accurately represent actual age-specific patterns of maternal mortality.

A recent study by Blanc and colleagues¹⁴ assessed age-specific maternal mortality in 38 countries. As a check on the validity of our results, we reran our analysis for the same 38 countries and compared the overall maternal mortality ratios reported by Blanc and colleagues with our own estimates (figure 2). Blanc and colleagues' estimates were lower than ours, particularly in the older age groups, but the same basic J shape was evident in both analyses, despite the fact that the two studies used different methods, and Blanc and colleagues' estimates fall within our uncertainty estimates. Blanc and colleagues reported that the maternal mortality ratio for women aged 15–19 years was 28% higher than for those aged 20–24 years across the 38 countries, whereas the difference was 17% in our analysis.

In the first sensitivity analysis, the age-specific maternal mortality ratios for Mexico, Russia, South Africa, and the USA varied over the time period covered by the analysis (table 5). In Mexico, Russia, and the USA, the results showed the same overall shape whether the calculations were done for the full 10-year period or either of the two 5-year periods that comprised the 10-year period, suggesting that, for these countries, the use of a 10-year period did not mask much variation in terms of the maternal mortality ratio for the 15–19 years age group relative to those for the older age groups. In South Africa, the adolescent maternal mortality ratio was slightly lower than the maternal mortality ratio for women aged 20–24 years in the first 5-year period, and slightly higher in the second 5-year period, and hence the two were the same across the full 10-year period. This finding suggests that, for some countries, the use of a 10-year period might have masked variations in the overall pattern.

The second sensitivity analysis assessed the effect of assuming that all age-unknown deaths (maternal or otherwise) in Colombia and Peru were of women aged 15–19 years, as opposed to distributing them proportionally across all the 5-year age groups as in the main analysis (table 6). This assumption was the most extreme scenario, which in both countries had the effect of lowering the maternal mortality ratio for the 15–19 years age group—ie, removing the J shape of the curve (which, for these two countries, was very slight anyway). This result suggests that the decision to distribute the age-unknown deaths proportionally across

the age groups might have resulted in the excess risk for adolescents being slightly exaggerated in some countries. However, this issue is unlikely to have affected the regional estimates, since most countries had few, if any, maternal deaths of unknown age.

In the final sensitivity analysis, the effect of removing or exaggerating the age-specific adjustment factors was non-existent for the age 25 years and older age groups, and for the two younger age groups the effect was negligible for countries without vital registration data because the adjustment factors to compensate for under-reporting were very small in the first place and tended to be more or less cancelled out by adjustments to compensate for misclassification. For countries with vital registration data, the age-specific adjustment factors had little effect when

	15–19 years	20–24 years	25–29 years	30–34 years	35–39 years	40–44 years	45–49 years
Mexico							
2000–09	40	39	53	93	150	340	230
2000–04	43	43	58	97	170	380	220
2005–09	36	35	48	89	140	310	230
Russia							
1998–2007	33	25	37	65	160	310	740
1998–2002	39	31	48	91	230	460	1100
2003–08	27	20	30	47	99	200	510
South Africa							
1999–2008	130	130	240	370	400	330	160
1999–2003	110	130	220	290	310	250	140
2004–08	140	130	260	450	510	420	180
USA							
1999–2008	11	13	6	19	31	70	450
1999–2003	14	15	4	24	39	74	222
2004–08	11	14	4	20	33	76	600

Data are maternal mortality ratios (maternal deaths per 100 000 livebirths).

Table 5: Age-specific maternal mortality ratios for four countries, disaggregated into two 5-year periods

	Colombia		Peru	
	Age-unknown deaths distributed proportionally	All age-unknown deaths assumed to be in the 15–19 years age group	Age-unknown deaths distributed proportionally	All age-unknown deaths assumed to be in the 15–19 years age group
15–19 years	66	43	59	45
20–24 years	65	65	57	56
25–29 years	96	96	73	73
30–34 years	140	140	100	100
35–39 years	240	240	170	170
40–44 years	290	290	280	280
45–49 years	570	570	350	350

Data are maternal mortality ratios (maternal deaths per 100 000 livebirths).

Table 6: Age-specific maternal mortality ratios for two countries, with different treatment of age-unknown deaths

	15–19 years age group			20–24 years age group		
	All age groups adjusted by the same factor	Adjustment factors as shown in table 2	Exaggerated adjustment factors	All age groups adjusted by the same factor	Adjustment factors as shown in table 2	Exaggerated adjustment factors
Argentina	33	35	44	37	34	25
Egypt	17	18	23	29	27	19
Italy	5	6	7	3	3	2
Romania	13	14	17	18	17	12
Trinidad and Tobago	36	39	32	48	30	21

Data are maternal mortality ratios (maternal deaths per 100 000 livebirths).

Table 7: Maternal mortality ratios for 15–19 and 20–24 years age groups for five countries with vital registration data, with different adjustment factors applied

the resultant maternal mortality ratios were compared with those that would have been seen had all age groups received the same adjustment factor (table 7). If, however, the extent of under-reporting is much greater in adolescents than in the other age groups, the age-specific estimates of maternal mortality ratio would be changed substantially, particularly in countries with high maternal mortality ratios. Countries with similar maternal mortality ratios in the 15–19 years and 20–24 years age groups do show a J-shaped age curve if the exaggerated adjustment factors are applied. However, countries with a J-shaped curve retain the same J shape irrespective of the adjustment factor; it merely becomes more or less pronounced as the adjustment factors are varied. The overall patterns seen in the regional estimates (figure 1, table 3) are therefore very unlikely to have been much affected by the assumptions made about adjustment factors.

Discussion

Our study shows that the excess risk of maternal mortality for adolescents is smaller than expected when compared with some previous subnational studies,^{26–29} although in most countries adolescents have an increased risk compared with women in their early 20s. Our analysis, however, goes further than most previous analyses, since it compares the 15–19 years age group with all other age groups, rather than only with women in their early 20s. For most countries, the risk of maternal mortality for adolescents is no greater than for women older than 30 years, and compared with women aged 35 years and older the risk is substantially lower for adolescents (panel).

One of the most notable features of these results is variation between different countries, with no clear country groupings in terms of pattern of age-specific maternal mortality; both developed and developing countries, and countries from all geographical regions, are represented in the groups that have ratios for adolescent maternal mortality ratios lower or higher than for women in their early 20s. Many of these differences could potentially be caused by data limitations. For many countries, the number of maternal deaths within each

5-year age group on which these estimates are based was very small, making the drawing of any clear conclusions difficult, and widening the uncertainty estimates. Other potential data limitations result from under-reporting of adolescent maternal deaths. Even for countries with vital registration data, maternal deaths are often under-reported,³⁰ and our knowledge about the extent to which under-reporting is affected by age is limited to two studies^{23,24} that suggest it is greater for younger women than for other age groups. For countries in which our analysis was based on survey data, adolescent maternal deaths might be under-reported because of concealed pregnancies or deaths related to unsafe abortions.

Age-disaggregated analyses of more recent vital registration data than were included in our analysis might show that the adolescent maternal mortality ratio is affected by recent changes to the way in which maternal death is classified. In 2012, WHO published *The WHO application of ICD-10 to deaths during pregnancy, childbirth and puerperium: ICD MM*,³¹ to guide countries to reduce errors in coding maternal deaths and to improve the attribution of cause of maternal death. This guidance made clear that, for the first time, pregnancy-related suicide was to be included as a direct cause of maternal death. If maternal suicide disproportionately affects adolescents, future analyses could show that the increased risk of maternal death for adolescents is greater than suggested by our results.

However, data limitations alone would seem unlikely to fully account for the heterogeneity seen between countries. An important question is therefore whether an increased risk of adolescent maternal mortality results from physiological or biodemographic factors, or from underlying characteristics (eg, poverty and low educational attainment) that are more prevalent in adolescent girls than in older women. Conde-Agudelo and colleagues¹⁹ reported no significant increased risk of mortality for women aged 16–19 years once adjustments had been made for a range of confounding variables (including parity, education, marital status, smoking, and number of antenatal visits). The heterogeneity between countries in our results might therefore be a reflection of how the

effect of these underlying factors differs by country. In many countries, adolescent births are likely to be concentrated among poorer, rural, and less educated populations, all of whom have an increased risk of mortality, mostly due to poor access to health care. Evidence from some countries also suggests that adolescents have poorer access to antenatal and delivery care than older women, even when the analysis has been adjusted for socioeconomic factors.³² Because most maternal deaths are preventable with prompt treatment, the extent to which adolescent births are concentrated within populations with poorer access to high-quality maternal health care will affect the ratio of adolescent maternal mortality to those of other age groups.

When biodemographic factors are taken into account, adolescents are more likely to be primiparous than older women, which is associated with increased mortality risk.³³ Although this risk is likely to be constant across countries, possible age differences and patterns in first births between countries could partly account for differences in risk. Where first births are heavily concentrated in other age groups, comparisons with adolescent maternal mortality ratio could be affected; alternatively, in countries where a substantial proportion of women have more than one birth in adolescence, the risk could be reduced.

In terms of physiological risk, the evidence is somewhat conflicting, but some evidence suggests that young women are at increased risk of several direct causes of maternal mortality such as eclampsia^{26,27} and obstructed labour,³⁴ as well as indirect causes such as malaria.³⁵ A study¹⁹ in Latin America also showed increased risks of haemorrhage and sepsis in young women, particularly those younger than 16 years.¹⁹ In Africa roughly 25% of unsafe abortions are done on women aged 15–19 years, and several studies have shown the resultant deaths to be a major cause of maternal mortality in this age group in some countries.²⁸ If the apparently increased risk of adolescent maternal mortality is related to physiological factors, the differences might reflect variation by region in cause of death. Evidence for how causes of death differ geographically is very sparse, particularly in developing countries, but what evidence there is does suggest that regional variations exist.³⁶ A higher frequency of conditions of greater risk in adolescents than in older women in some countries could translate to an increased risk of death.

A further possible explanation for how physiological factors could produce variations in the risk ratios between countries is the age at which adolescents give birth. Compelling evidence shows that young adolescents (ie, those younger than 15 or 16 years) have a greatly increased risk of morbidity and mortality compared with older adolescents,^{19,29} so countries where childbearing starts at a younger age show a greater comparative risk of adolescent pregnancies. Indeed, when we compare our results with country estimates for adolescent pregnancy in girls younger than 16 years, some countries where a

Panel: Research in context

Systematic review

We did not do a systematic review, but did a standard review of the scientific literature. We searched Medline for reports of studies published from Jan 1, 1980, to June 30, 2012, that presented data for adolescent maternal mortality (either as an age-specific maternal mortality ratio or expressed as a relative risk by comparison with other age groups). The search terms used included “adolescent” or “teenage”, and “maternal mortality” or “maternal death”. Although we found several studies from developed countries with good national estimates of adolescent maternal mortality based on vital registration data,^{15–18} those from developing countries tended to have serious limitations. Many were not nationally representative, used age groupings that were not consistent to allow comparison,²⁷ or were facility-based rather than community-based^{19,27} (for additional references see appendix p 14). The evidence generally suggested that adolescents have a greater risk of maternal mortality than women aged 20–24 years, and that this difference is more substantial in developing than in developed countries.

Interpretation

Our study of data from 144 countries is the most comprehensive analysis of country-level, age-specific estimates of maternal mortality developed so far, and is based on the best available data from vital registration, sample health surveillance, and nationally representative surveys in both developed and developing countries. Whereas in the aggregate results for all countries we noted the previously reported J-shaped curve, wherein adolescents have higher maternal mortality ratios than women aged 20–24 years, analysis of individual countries and world regions showed variation in age-specific patterns of maternal mortality. Our aggregate findings suggest that the increased risk of mortality associated with adolescent pregnancy compared with pregnancy in women aged 20–24 years might not be as great as previously believed. Additionally, maternal mortality ratios for women aged 30 years and older were generally higher than for adolescents, suggesting that clinicians should consider ways to reduce mortality in these older age groups. However, clinicians and public health practitioners should not be deterred from making efforts to reduce adolescent pregnancy, which remains an important issue with respect to women’s educational, social, and economic development.

high proportion of girls become mothers before age 16 years have a higher maternal mortality ratio for the 15–19 years age group than for the 20–24 years age group.⁴ However, some results are anomalous—eg, in Rwanda both adolescent fertility and fertility for girls younger than 16 years are very low, but the country has a much higher maternal mortality ratio for women aged 15–19 years than for those aged 20–34 years. Further research is needed to identify the factors that account for these different patterns.

Another notable finding from this study is the very high maternal mortality ratios for women aged 35 years and older, which in many countries and regions apply even when the ranges of uncertainty are taken into account. In many countries this increased risk becomes apparent from age 30 years. Although it has long been understood that older women are at an increased risk of maternal death, no previous study has presented data from such a large range of countries, making our findings highly compelling. Further analysis of this result is currently underway, and will be reported separately.

Our finding of a fairly small excess mortality associated with pregnancy in adolescence should not detract from

the message that adolescent reproductive health should remain a priority for both national governments and the global health community. In many countries the risks that adolescents face in giving birth are still severe, and countries with high adolescent fertility are often also those with unacceptably high overall maternal mortality. Furthermore, this study did not attempt to quantify the risk of severe morbidities for adolescent mothers, such as obstetric fistula, which can result in lifelong disability and disadvantage. Reduction of adolescent births is also crucial in breaking the cycle of deprivation in young women through ensuring access to continued education and livelihood opportunities.

Contributors

AVC conceived the study and began working on it while employed by WHO. AN and ZM devised the study design, basing it on the method used by WHO, UNICEF, the UN Population Fund, and the World Bank for their periodic country-specific maternal mortality estimates. AN reviewed the scientific literature, did the calculations on which the results are based, and wrote the methods section and parts of the results and discussion sections. ZM worked with AN on the scientific literature review and calculations, and wrote the introduction and parts of the results and discussion sections. SN wrote the summary and parts of the results and discussion sections. All authors approved the final draft of the report.

Conflicts of interest

We declare that we have no conflicts of interest.

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